Supplementary Information

Growth mechanism of AlN on hexagonal BN/sapphire substrate by metal-organic chemical vapor deposition

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I. AFM images of hBN and hBN-O\textsubscript{2} layers on sapphire

Fig. S1 shows the AFM images of hBN layer on sapphire with/without O\textsubscript{2} plasma treatment (hBN-O\textsubscript{2}/hBN). The wrinkles (the bright wires) and multilayer islands (the bright regions) are clear on the surface of hBN layer, which is consistent with the SEM image. Meanwhile, the AFM image of hBN-O\textsubscript{2} layer is consistent with the SEM image for the decrease of wrinkles.

![AFM images of hBN and hBN-O\textsubscript{2} on sapphire](image)

Fig. S1 AFM images of hBN and hBN-O\textsubscript{2} on sapphire

II. Experiment results of 1.45-μm AlN grown on sapphire

Fig. S2 shows the results of AlN directly grown on sapphire. Fig. S2(a) presents the AlN on sapphire has a smooth and flat surface, and the RMS roughness in the 5×5 μm\textsuperscript{2} area is only 0.22 nm. Fig. S2(b) and Fig. S2(c) show the ω-scan (rocking curve) profiles of (0002) and (10-12) AlN, respectively. As estimated from the XRD FWHM, the densities of screw and edge dislocations are 1.55×10\textsuperscript{8} cm\textsuperscript{-2} and 9.53×10\textsuperscript{9} cm\textsuperscript{-2}, respectively.
Fig. S2 Experimental results of AlN on sapphire: (a) AFM image, X-ray rocking curves of (b) (0002) and (c) (10-12) 
AlN grown on sapphire (the number is FWHM value)

III. AFM images of 2-min LT-AlN

Fig. S3 shows the AFM images of the LT-AlN films grown for 2 min on hBN/sapphire, hBN-O₂/sapphire and 
sapphire. Some hBN multilayer islands can be observed on hBN/sapphire and hBN-O₂/sapphire. At the same time, 
AlN on hBN-O₂ presents the different morphology comparing with the hBN-O₂ layer before the growth of LT-AlN 
while the surface of AlN on hBN is nearly the same as the hBN layer before the growth. The uniform AlN islands 
even cover all the surface of hBN-O₂/sapphire on these regions without hBN multilayer islands, corresponding 
with the morphology of AlN islands on sapphire. These AFM results are consistent with the SEM results.

IV. Crystal orientation of the AlN films on hBN/sapphire and hBN-O₂/sapphire

Fig. S4 shows the XRD pole figures of (10-12) reflections (2θ =49.9°) of AlN located at ψ= 42° and (11-23) 
reflections (2θ =43.4°) of sapphire located at ψ= 60° and ψ= 63° with the hBN and hBN-O₂ release layers. It’s 
obviously that AlN on the two substrates shows a clear six-fold rotational symmetry from the (10-12) poles of AlN 
films indicating the consistent in-plane crystal orientation of AlN domains. Moreover, the φ values with the 
maximum reflection intensity of (10-12) reflections of AlN are approximately equal to the φ values with the 
maximum reflection intensity of (11-23) reflections of sapphire (The measurement accuracy of the XRD pole 
figure used in our work is 3°.), as shown in table S1. So the two AlN epitaxial layers are both crystallographically 
rotated by 30° with the structures of (0001)[10-10]AlN||(0001)[11-20]sapphire.

Table S1 the φ values of AlN (10-12) pole and sapphire (11-23) poles

<table>
<thead>
<tr>
<th>release layer</th>
<th>reflection</th>
<th>ψ (°)</th>
<th>Φ (°)</th>
<th>ψ (°)</th>
<th>Φ (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>hBN AlN (10-12)</td>
<td>42</td>
<td>4.5</td>
<td>64.5</td>
<td>121.5</td>
<td>181.5</td>
</tr>
<tr>
<td>sapphire (11-23)</td>
<td>63</td>
<td>4.5</td>
<td>64.5</td>
<td>121.5</td>
<td>181.5</td>
</tr>
<tr>
<td>hBN-O₂ AlN (10-12)</td>
<td>42</td>
<td>1.5</td>
<td>61.5</td>
<td>118.5</td>
<td>178.5</td>
</tr>
<tr>
<td>sapphire (11-23)</td>
<td>63</td>
<td>4.5</td>
<td>64.5</td>
<td>121.5</td>
<td>181.5</td>
</tr>
</tbody>
</table>
V. The transfer process of hBN layer by the aid of PMMA

i) The thin film layer of 4.5% PMMA diluted in anisole was spin coated onto the better hBN side of the Cu foil to support and protect hBN layer.

ii) The PMMA/hBN/Cu sample was baked at about 110 °C for 15 min and then cooled to room temperature.

iii) The hBN on the backside of the Cu foil was washed away by DI water after etching in 10% ferric trichloride solution for 10 seconds.

iv) The Cu substrate continued to be set in the solution for several hours until the etching procedure was done.

v) DI water washed the sample to remove contamination from the solution.

vi) The hBN/PMMA films were transferred onto c-plane sapphire substrate and dried in the air.

vii) The sample was baked at 110 °C for 1 hour to reduce numerous wrinkles in the hBN layer.

viii) PMMA was removed by acetone. Finally, the sample was annealed at around 550 °C under a H₂ atmosphere for 30 min to eliminate the PMMA residues and the transfer of the hBN was accomplished.